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CURRENT STATUS, STRUCTURE, AND PLANT SPECIES COMPOSITION OF THE RIPARIAN VEGETATION OF THE TRUCKEE RIVER, CALIFORNIA AND NEVADA

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ABSTRACT

Although riparian areas are a critical component of biodiversity in arid lands, our knowledge of many major rivers of the western United Startes remains limited. The Truckee River of California and Nevada is typical, with a general lack of published data on its riparian vegetation. Cover type mapping of eight reaches shows that the relative proportions between natural vegetation and cultural land-use types vary. Despite impacts from logging, railroad and highway construction, and water resource development, riparian vegetation along the upper three reaches is currently dominated by native riparian species. In the remaining reaches large proportions of the floodplain have been converted to urban and industrial or agricultural uses, or have been disturbed and are dominated by introduced weeds. Downstream reaches have also been more affected by flow regulation, water diversions, and related impacts. The lower reaches also, however, offer the greatest opportunities for restoration and enhancement of the riparian corridor. Data is also presented on the current plant species composition and structure of natural riparian vegetation which, in conjunction with hydrological data, can help land managers and biologists to formulate strategies for wildlife habitat enhancement.

Riparian areas are a critical component of biodiversity within the arid lands of the western United States and their importance is amplified by the minor proportion of the overall area which they occupy (Carothers 1977). Despite an increasing emphasis on the ecology and management of western riparian ecosystems over the past two decades (e.g., Johnson and Jones 1977; Warner and Hendrix 1984; Johnson et al. 1985; Knopf et al. 1988; Abell 1989; Clary et al. 1992), there remains a striking lack of published basic ecological data on many major western rivers. The Truckee River, one of three large rivers which drain eastward from the Sierra Nevada to sinks in western Nevada is typical, with refereed publications infrequent and of narrow focus. Papers have appeared regarding food preferences and demographics of beaver (Hall 1960; Busher et al. 1983), local flora (Savage 1973; Smith 1984), historical avifaunal changes along the lower Truckee River (Klebenow and Oakleaf 1984), and seed germination in *Salix* (Martens and Young 1992).

The Truckee River drains a 3100 km^2 basin in the Sierra Nevada into Pyramid Lake (elevation 1160 m), Nevada (Fig. 1). From Lake Tahoe (elevation 1899 m), the river flows 174 km through steep mountain canyons and narrow valleys, passes highly urbanized areas near the city of Reno, and continues through high desert canyons and irrigated agricultural land in broader valleys to its terminus. Significant development of natural resources in the Truckee River drainage began in the 1860's with extensive logging to provide timber to the nearby mining boomtown, Virginia City, and for railroad ties and snowsheds along the route of the Central Pacific Railroad (California Department of Water Resources 1991). Much of the Lake Tahoe Basin and the surrounding area was stripped of trees and the logs were transported by flumes along the river, as well as down the river channel itself.

Prior to the turn of the century, numerous dams had been built at the outlets of lakes, including one at the outlet of Lake Tahoe constructed in the early 1870's (California Department of Water Resources 1991). Subsequent to the passage of the Reclamation Act of 1902, the U.S. Bureau of Reclamation became the major developer of water projects on the Truckee River. Derby Dam, downstream of Reno, was this agency's first construction project (Fig. 1). Completed in 1905 as part of the Newlands Project, the dam and its conveyance canal were designed to transfer water from the Truckee River to arable land with little rainfall in the adjacent Carson River drainage. Irrigation water supplied by the project continues to be the single largest use of Truckee River water.

As a result of this water diversion, a steep decline in the water surface elevation of Pyramid Lake began in about 1910. The lake elevation reached a low point in the late 1960's at about 23 m below its pre-Derby Dam diversion level. In response, the lower eight km of the river channel widened and incised into its floodplain, stranding the adjacent river terraces (Born 1972; Water Engineering & Technology, Inc. 1991). Channelization of the river during the 1960's led to further

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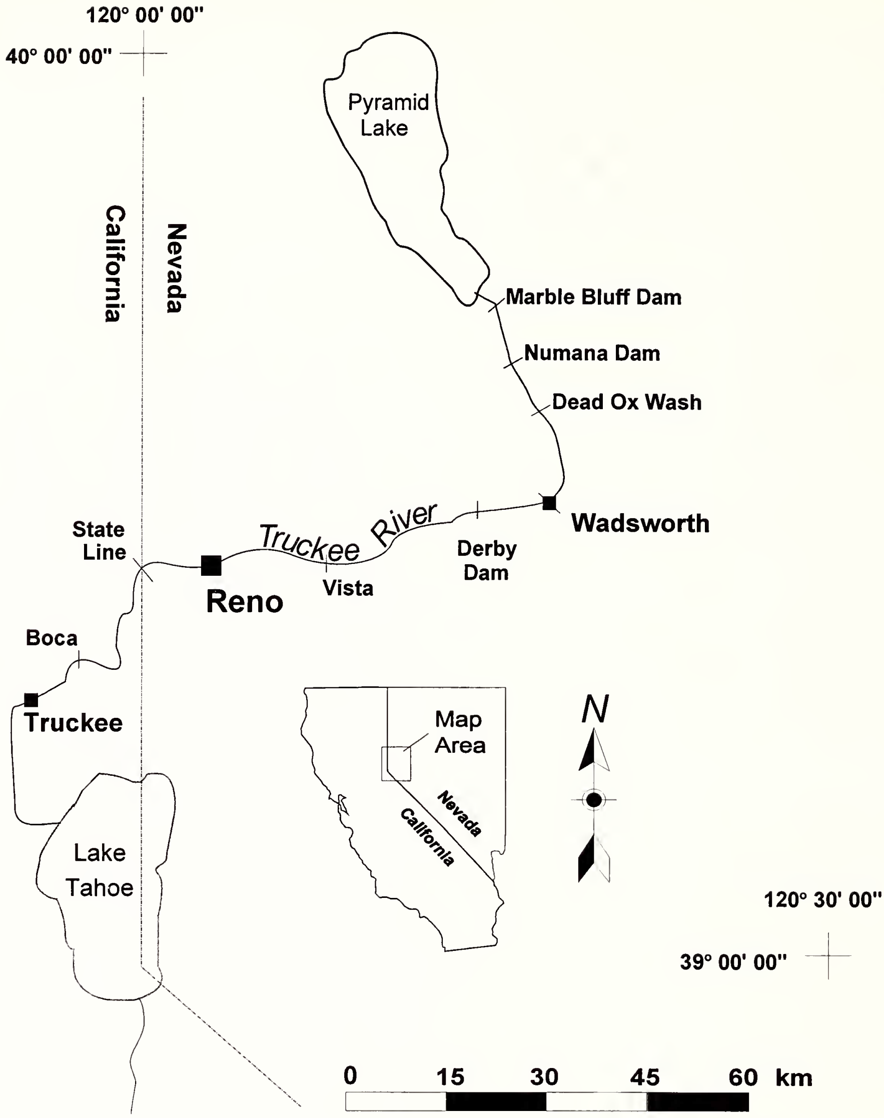

FIG. 1. Location of the study area along the Truckee River, California and Nevada. Urban areas and boundaries of the eight reaches are shown.

incision downstream of Wadsworth (Glancy et al. 1972). Since about 1990, the lake elevation has been about 15 m below the pre-Derby Dam level.

Federal reservoirs for water storage and flood control in the Truckee River watershed and their construction dates include Boca (1937), Prosser Creek (1962), and Stampede Reservoir (1970), all owned by the Bureau of Reclamation, and Martis Creek (1971), owned by the U.S. Army Corps of Engineers. These reservoirs combined provide about 317,000 acre-feet of usable storage. Numerous smaller non-Federal reservoirs and diversions are located in the Truckee River watershed.

In an attempt to reduce water loss due to evapotranspiration, beaver (*Castor canadensis*) were introduced to the drainage in the late 1940's (Hall 1960). Evidence of beaver activity, primarily gnawed trunks, is present throughout the river corridor although serious impacts seem highly localized.

This study was restricted to the riparian corridor along the 174 river kilometers of the mainstem of the Truckee River from Lake Tahoe Dam to Marble Bluff Dam. In this paper, I present baseline data on the vascular plant species composition, structure, and areal extent of the existing riparian vegetation of this area in order to provide a framework for future ecological research.

METHODS

Terminology. Throughout this paper, the terms "riparian" and "riparian corridor" are used in the functional sense of a "three-dimensional zone of interaction between terrestrial and aquatic ecosystems" (Gregory et al. 1991). As such, the riparian zone includes, at a minimum, the low-flow and active river channels and the inferred historic floodplain. Because of the vertical component of the definition, the riparian zone upstream of State Line may also include, as a minor component, lower hillslopes supporting coniferous forests. It is important to note that "riparian" as used in this paper is not synonymous with "wetland" in a jurisdictional sense. In most areas downstream of Reno, and especially downstream of Derby Dam, flow regulation and water diversion have altered the natural hydrography of the river and contributed to lowered groundwater tables with a consequent shift toward a less hydrophytic vegetation. As noted earlier, this effect has been most profound in the lower eight km of the river upstream of Pyramid Lake.

Cover type mapping. The 174 km river corridor was subdivided into eight reaches based on morphological, geological, and hydrological characteristics. The reaches vary in length, stream gradient, floodplain area, and the ratio between floodplain area and reach length (Table 1). The latter is an indicator of the local constraints imposed on the channel and valley floor by geomorphic features and, by extension, the width of the riparian corridor (Gregory et al. 1991). Natural vegetation and land use types within the riparian zone were mapped on acetate overlays of enlarged black-and-white aerial photography at a scale of 1:1200. Source photos for these enlargements were flown on November 4, 1991; the scale of the original photos was 1:12,000. Cover type polygons were manually delineated. The minimum mapping criterion for forested types was at least six trees (as defined below) in an area of 0.2 ha. The overlays were scanned into AUTOCAD and areas were calculated for each cover type by polygon. Areas adjacent to, and enroute to, field sample sites were field checked for boundary and classification accuracy and revised accordingly. Because of interpretation difficulties, some non-forested areas outside of the historic floodplain may have been incorrectly included. These inaccuracies are believed to have resulted in only minor overestimates of the extent of the riparian zone downstream of Reno.

Data collection. Data on plant species composition and abundance were collected only from natural vegetation types, excepting marshes and ponds, along 31 transects at 11 sites. Sites were chosen to be representative of general conditions with the study reaches and to isolate, to the extent possible, river hydrology as a controlling variable for vegetation from other hydrological influences (e.g., irrigated pastures above channel banks, unlined irrigation canals, springs, sewage effluent runoff, and significant grading and fill placement). An additional constraint was relative proximity to stream

TABLE 1. RIVER LENGTH, CHANGE IN ELEVATION, RIVER GRADIENT, RIPARIAN ECOSYSTEM AREA, AND THE RATIO OF FLOODPLAIN AREA TO RIVER LENGTH FOR THE EIGHT TRUCKEE RIVER STUDY REACHES. The ratios are measures of stream gradient and width of the riparian corridor, respectively. Lake Tahoe outlet dam lies at 1899 m, Marble Bluff Dam at 1176 m.

Reach	Length (km)	Elevation change (m)	Gradient (m/km)	Area (ha)	Corridor ratio (ha/km)
Lake Tahoe to Boca	37.03	222.20	6.00	166.37	4.49
Boca to State Line	20.93	152.40	7.28	206.81	9.88
State Line to Vista	37.03	183.88	4.97	393.86	4.96
Vista to Derby Dam	27.37	60.96	2.23	537.97	19.66
Derby Dam to Wadsworth	17.71	30.48	1.72	403.32	22.77
Wadsworth to Dead Ox	16.10	39.62	2.46	505.24	31.38
Dead Ox to Numana Dam	6.44	15.24	2.37	72.76	11.30
Numana to Marble Bluff Dam	11.27	18.22	1.62	422.18	37.46
Total	173.88	723.00	4.16	2708.51	15.58

gages so that channel hydraulics could be calculated in order to relate flow rates to topographic inundation. Areas with extensive recent activity by beavers were avoided, as were areas of recent logging or fuelwood cuttings. The transects were oriented perpendicular to the river channel and varied in length according to the width of the riparian zone. A total length of 3380 m was sampled. Data were collected by structural layer according to the following definitions and procedures:

Tree layer.—Single- or multiple-stemmed woody plants $\geq$ 6 m in height and $\geq$10 cm diameter-at-breast height (dbh). Data were collected on dbh and density within 15 m of the transect (i.e., a 30 m belt transect). Stand canopy coverage was estimated by species at random locations along the transect using a spherical densiometer. Average stand canopy height was estimated using a clinometer.

Shrub layer(s).—All woody plant species $<$ 6 m in height or $<$ 10 cm dbh. Canopy coverage was estimated visually along each transect using the line-intercept method (Mueller-Dombois and Ellenberg 1974). Data were collected in three height classes: tall shrubs ($>$3 m), medium shrubs ($>$1 m and $\leq$3 m), and low shrubs ($\leq$1 m).

Herbaceous layer.—Non-woody species including herbs, grasses, and graminoids. Canopy coverage visually estimated by species using the line-intercept method.

Ground surface.—Ground surface data on brushpiles, litter, and bare ground was tallied using the line-intercept method. Bare ground was further recorded as clay, sand, gravel, cobbles, or boulders.

Other information collected included site elevation (taken from topographic maps), transect orientation (measured from aerial photos), current land use, and evidence of recent disturbance (e.g., grazing, beaver activity). The taxonomic reference for all plant scientific names is Hickman (1993).

Data analysis. The areal coverage of individual vegetation and land use types was calculated by reach. Vegetation data from the transects were summarized for transect segments stratified by physiognomic type (forest, shrub, herbaceous). Each segment was treated as a sample of its physiognomic type. The total of 178 samples were subjected to Two-way Indicator Species Analysis (TWINSPAN), a hierarchical classification procedure (Hill 1979; Gauch and Whittaker 1981); the TWINSPAN output was further refined based on the field experience and professional judgement of the investigator.

Results

Physical characteristics. Physical characteristics of each of the eight reaches are provided in Table 1. The disparity in reach lengths is due to the variety of geologic and topographic settings through which the Truckee River passes along its course from the Sierra Nevada to Pyramid Lake. This is also reflected in the river gradient which generally decreases from Lake Tahoe to Pyramid Lake. There is a corresponding general increase in the width of the riparian corridor. Exceptions to this trend occur in the State Line-Vista and Dead Ox-Numana Dam reaches, where the river passes through narrow bedrock canyons.

Cover type mapping. Four major categories of aquatic ecosystem, natural vegetation, and cultural types were mapped (Fig. 2). These include: 1) the active channel of the river including the low-flow wetted channel; 2) riparian forest and riparian shrub communities on the floodplain; 3) cultural types on the floodplain; and, 4) upland forest and upland shrub communities. The boundaries of the low-flow wetted channel were based on the area covered by water on the November 4th date of the aerial photographs. Also occurring within the active channel were sparsely-vegetated cobble bars and patches of graminoids and herbs, here referred to as the vegetated streambed. There is a dynamic relationship among these three elements of the active channel. The boundaries of the low-flow wetted channel expand and contract in response to annual climatic variation, and water regulation or diversion. Channel scour during high flows leads to an increase in the amount of cobble bars. Conversely, the absence of scouring flows results in an increase in the total area of vegetated streambed. Because this study was conducted during the sixth consecutive year of drought, the ratio of vegetated streambed within the active channel was greater than normal, when compared to either the cobble bars or the low-flow wetted channel. Overall, the active channel comprises about 25% of the riparian corridor, although in the steep, narrow canyons which characterize the Lake Tahoe-Boca and Dead Ox Wash-Numana Dam reaches, this value increases to 51% and 38%, respectively (Fig. 2).

Riparian forest and riparian shrub communities occur on the floodplain of the river in most reaches. Deciduous riparian forests comprise between 2% and 20% of the riparian corridor upstream of Reno, with the lowest percentage occurring above Boca (Fig. 2). Downstream of Reno, the range is narrower (6% to 18%), although no riparian forest occurs in the Dead Ox-Numana Dam reach (Figs. 2, 3). A similar pattern is seen in the riparian shrub communities. Upstream of Reno, riparian shrub communities comprise 22% to 28% of the riparian corridor (Fig. 2). Downstream of Reno, riparian shrub communities comprise 5% to 14% of the riparian corridor (Figs. 2, 3).

Cultural types were defined to include agricultural fields and facilities, urban and industrial areas, sites dominated by the noxious weed *Lepidium latifolium,* and other disturbed areas. The proportions of the riparian corridor occupied by these habitats is low to moderate (7%–29%) in the upper three reaches, high (45–60%) in the middle three reaches,

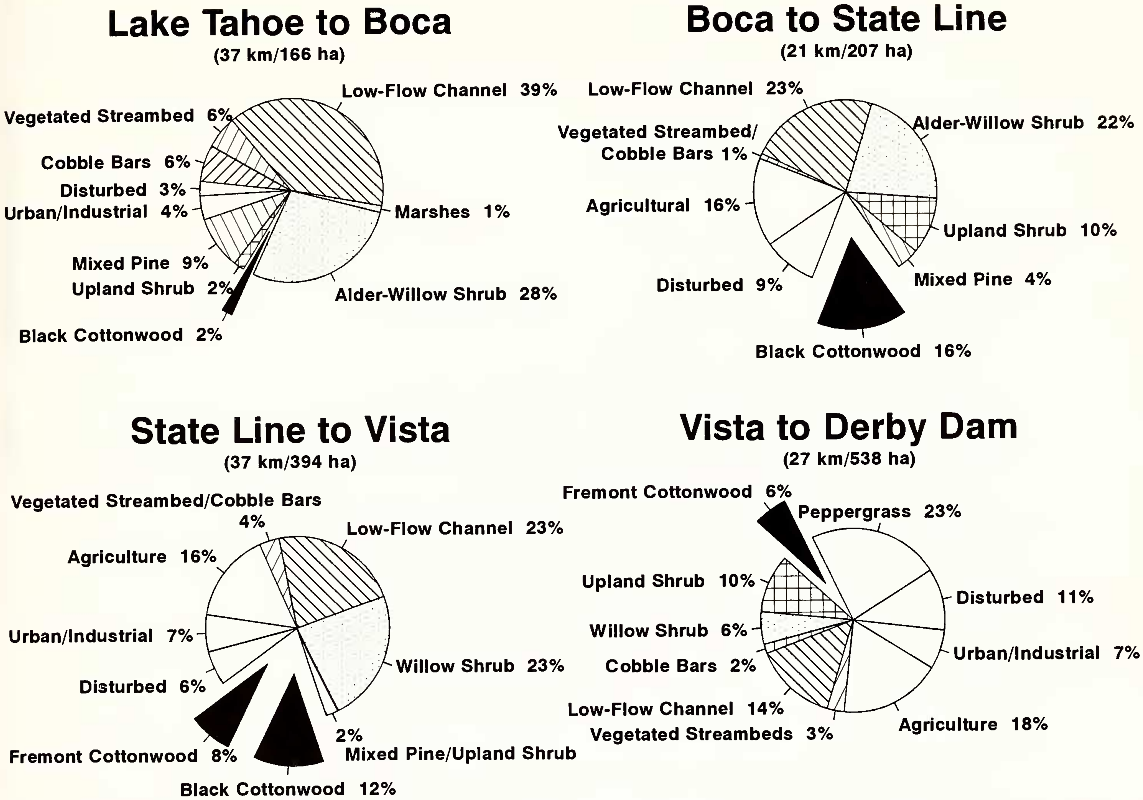

FIG. 2. Percentages of vegetation, aquatic, and land-use types for the upper four study reaches along the Truckee River. The length and area of riparian corridor is provided for each reach in parentheses.

and moderate (29–33%) in the lower two reaches (Figs. 2, 3).

Mixed pine communities occur on lower hillslopes adjacent to the floodplain only along the upper three reaches where they comprise 2% to 9% of the riparian corridor (Fig. 2). Upland shrub communities occur on the floodplain in all reaches where they account for 2% to 10% of the riparian corridor, except along the lower two reaches where they comprise 18% and 28% of the corridor (Fig. 3). Marshes and ponds occur in several reaches, but they never account for more than 1% in any reach in which they occur (Figs. 2, 3).

Species composition and abundance. The results of the TWINSPAN analysis supported distinctions between groups of samples of riparian forest, riparian shrub, vegetated streambed and cobble bar communities based on their occurrence upstream or downstream of Reno (Tables 2, 3). Upstream of Reno samples correspond roughly to the upper three study reaches, while samples downstream of Reno correspond to the lower five study reaches. Upland shrub communities showed no such distinction, perhaps due to the infrequent occurrence of this type along transects upstream of Reno. Upland mixed pine forests occur only along the upper three reaches.

Populus trichocarpa ssp. *balsamifera,* with 80% canopy coverage, is the dominant tree species in deciduous riparian forests along the upper three reaches (Table 2). A tall shrub layer with 15% cover, dominated by *Salix lutea,* is present. The only other riparian shrubs present are *S. exigua* and saplings of *P. trichocarpa* ssp. *balsamifera,* each with only a few percent cover. Minor amounts of upland shrubs also occur in this type. The understory is dominated by *Elymus trachycaulus* and *Poa pratensis* with 19% and 14% coverage, respectively. *Conium maculatum* and *Urtica dioica* are the dominant herbaceous species.

Both *Populus trichocarpa* ssp. *balsamifera* and *P. fremontii* ssp. *fremontii* (Fremont cottonwood) dominate individual deciduous riparian forest patches in the State Line-Vista reach, although no mixed stands of these species as canopy dominants were observed. Downstream of this reach, *P. fremontii,* with 70% canopy coverage, is the sole dominant tree in the riparian forests (Table 3). There is a conspicuous dearth of riparian shrubs in these forests, where tall shrubs of *P. fremontii* provide only about 8% cover. *Artemisia tridentata* ssp. *tridentata* is present in small amounts, and there is a sparse understory of *Elymus trachycaulus* and *Lepidium latifolium.*

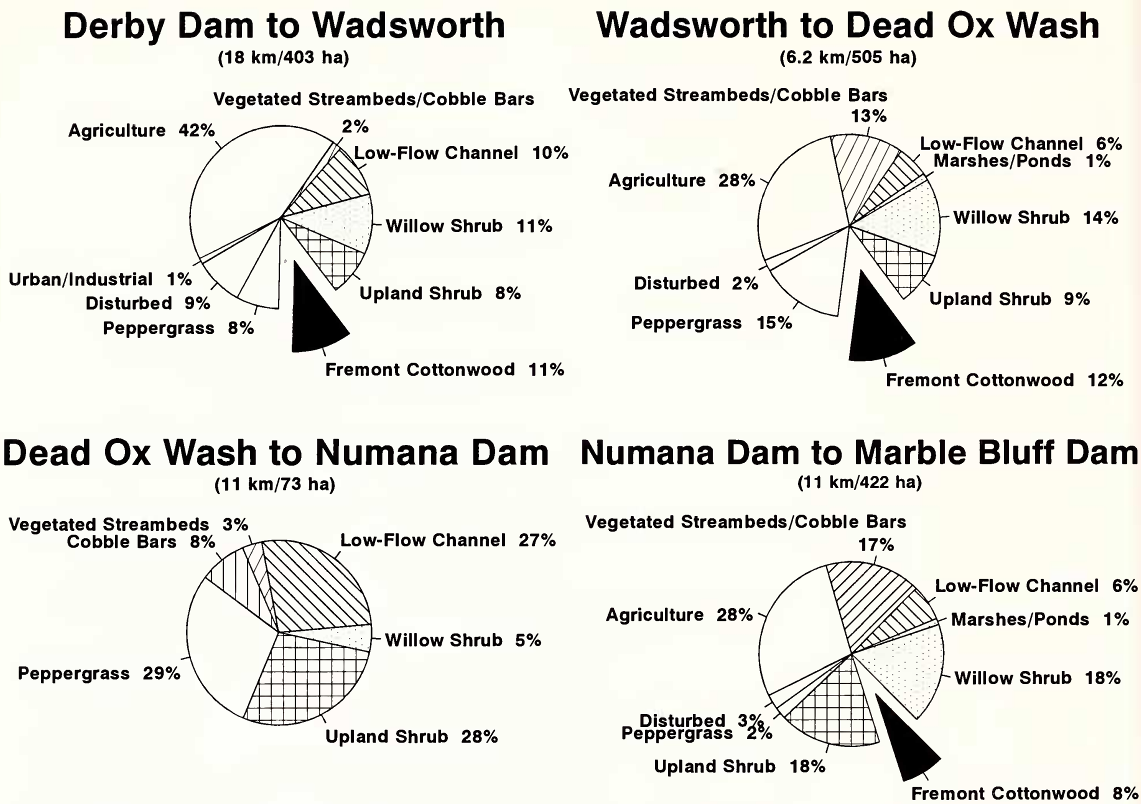

FIG. 3. Percentages of vegetation, aquatic, and land-use types for the lower four study reaches along the Truckee River. The length and area of riparian corridor is provided for each reach in parentheses.

A shift occurs in the dominant species of the riparian shrub communities which corresponds to that seen in the riparian forest, although the transition is more gradual. Upstream of Reno, tall and medium height shrubs of *Alnus incana* ssp. *tenuifolia* dominate this community, although numerous other riparian shrubs typically occur with it (Table 2). A wide variety of grasses, graminoids, and herbaceous plants make this the most diverse of all the habitats investigated. *Alnus incana* ssp. *tenuifolia* is much less common downstream of Reno, where the dominant species in the riparian shrub community is *Populus fremontii* ssp. *fremontii* of medium and low stature (Table 3). Numerous other riparian shrubs are associated with this type, and there is a well-developed grass, graminoid and herbaceous layer dominated by *Lepidium latifolium* with 21.8% coverage.

Vegetated streambed communities in the upper three reaches were dominated by *Poa pratensis* and *Elymus trachycaulus,* with 10.7% and 9.4% coverage, respectively (Table 2). *Carex aquatilis* and *C. utriculata* are common associates. Downstream of Reno, vegetated streambed communities are dominated by *Eleocharis acicularis* and *Lepidium latifolium* with 29.4% and 29.8% coverage, respectively (Table 3). *Scirpus americanus* and *Melilotus alba* are the most abundant associated species. Cobble bars are only sparsely vegetated in all reaches, but still differ distinctly in species composition. Upstream of Reno, *Carex utriculata* and *Glyceria striata* are the most abundant species (Table 2). Downstream of Reno, the most abundant species on cobble bars is *Lepidium latifolium* (Table 3).

Upland forests along the upper three study reaches are generally comprised of mixtures of *Abies concolor, Pinus jeffreyi,* and *P. contorta* ssp. *murrayana,* although pure stands of the latter species can be found. *Populus balsamifera* ssp. *trichocarpa* occurs infrequently in these forests (Table 2). Upland shrubs comprise about 26% coverage, while grasses and graminoids dominate the understory. Upland shrub communities are the predominant vegetation adjacent to the riparian corridor along the five lower reaches, where they occasionally extend onto the floodplain. *Artemisia tridentata* ssp. *tridentata* is the dominant species in this community (Table 3). The most abundant associated shrub species are *Chrysothamnus viscidiflorus* and *Shepherdia argentea.* Associated grasses include *Leymus cinereus* and *Bromus tectorum.* Because this study was conducted during the sixth consecutive year of drought, the abundance of the latter species

TABLE 2. PLANT SPECIES COMPOSITION AND ABUNDANCE IN RIPARIAN VEGETATION TYPES ALONG THE UPPER TRUCKEE RIVER, CALIFORNIA/NEVADA. Abundance values are absolute percent canopy coverage. Introduced species are marked with an asterisk. Total and mean transect lengths, and ground surface characteristics for each type are also included.

Name	Cobble bars (n=15)	Vegetated streambed (n=17)	Riparian shrub (n=40)	Riparian forest (n=4)	Mixed pine forest (n=12)
Total/mean transect length (m)	93.3/8.5	170.0/10.0	371.2/9.3	208.5/52.1	84.4/10.6
Trees					
Populus balsamifera ssp. *trichocarpa*	—	—	—	80.1	1.1
Abies concolor	—	—	—	—	16.7
Pinus jeffreyi	—	—	—	—	13.8
Pinus contorta ssp. *murranyana*	—	—	—	—	15.5
Layer Total	—	—	—	80.1	47.1
Tall Riparian Shrubs					
Alnus incana ssp. *tenuifolia*	—	—	19.1	—	—
Salix lutea	—	0.5	1.5	12.8	—
Salix melanopsis	—	0.6	0.7	—	—
Populus balsamifera ssp. *trichocarpa*	—	—	2.5	2.3	—
Layer Total	—	1.1	23.8	15.1	—
Medium Riparian Shrubs					
Alnus incana ssp. *tenuifolia*	—	1.4	23.0	—	1.1
Populus balsamifera ssp. *trichocarpa*	—	—	1.7	0.5	—
Salix lucida ssp. *lasiandra*	—	0.5	7.0	—	—
Salix lutea	—	—	5.4	1.5	—
Salix exigua	—	—	0.1	0.2	—
Salix melanopsis	—	—	0.5	—	—
Cornus sericea	—	—	0.3	—	—
Layer Total	—	1.9	38	2.2	1.1
Low Riparian Shrubs					
Salix exigua	0.6	0.1	1.4	—	—
Salix lutea	—	—	0.2	—	—
Populus balsamifera ssp. *trichocarpa*	0.1	0.3	1.9	0.2	2.4
Alnus incana ssp. *tenuifolia*	—	—	0.5	—	—
Salix lucida ssp. *lasiandra*	—	—	0.4	—	—
Cornus sericea	—	—	0.3	—	—
Salix melanopsis	—	—	0.1	—	—
Layer Total	0.7	0.4	4.8	0.2	2.4
Upland Shrubs					
Artemisia tridentata ssp. *tridentata*	0.1	0.8	0.1	0.1	5.5
Rosa woodsii var. *ultramontana*	—	1.3	2.7	0.3	5.8

TABLE 2. CONTINUED

Name Total/mean transect length (m)	Cobble bars (n=15) 93.3/8.5	Vegetated streambed (n=17) 170.0/10.0	Riparian shrub (n=40) 371.2/9.3	Riparian forest (n=4) 208.5/52.1	Mixed pine forest (n=12) 84.4/10.6
Chrysothamnus nauseosus	1.1	0.4	—	—	0.6
Chrysothamnus viscidiflorus	—	—	0.7	0.8	—
Ribes viscosissimum	—	—	0.4	—	3.4
Populus tremuloides	—	—	1.4	—	—
Amelanchier alnifolia var. *pumila*	—	—	—	—	6.5
Symphoricarpos rotundifolius	—	—	—	—	3.1
Purshia tridentata var. *tridentata*	—	—	—	—	0.7
Layer Total	1.2	2.5	5.3	1.2	25.6
Grasses and Graminoids					
*Poa pratensis**	1.5	10.7	6.1	14.1	2.2
*Hordeum brachyantherum**	0.2	2.3	0.2	4.6	8.8
Carex subfusca	1.0	1.7	4.7	—	—
Glyceria striata	2.3	0.4	4.6	—	—
Carex athrostachya	1.0	3.3	0.6	—	—
Alopecurus aequalis	0.2	2.2	0.8	—	—
Agrostis exarata	0.1	2.9	0.6	—	—
Juncus mexicanus	1.4	—	—	0.2	1.6
*Dactylis glomerata**	0.6	—	—	—	—
Scirpus microcarpus	0.5	—	0.5	—	—
Carex utriculata	6.7	5.1	1.0	—	—
Carex aquatilis	—	5.1	1.1	—	—
*Phalaris arundinacea**	—	1.2	0.9	—	—
Juncus effusus	—	—	0.4	—	—
Carex lenticularis	—	—	0.2	—	—
Carex lanuginosa	—	—	0.2	—	—
Achnatherum occidentalis	—	—	0.1	—	0.2
Elymus trachycaulus	—	9.4	5.9	19.4	5.1
Juncus balticus	—	—	0.1	0.2	—
*Bromus tectorum**	—	—	0.6	2.2	2.8
Calamagrostis rubescens	—	—	—	—	3.1
Layer Total	15.5	44.3	28.6	40.7	23.8
Herbs					
Epilobium ciliatum	1.8	0.1	0.6	—	—
Mimulus guttatus	0.3	2.0	0.5	—	—
*Melilotus alba**	0.4	1.4	0.3	—	—
Sphenosciadium capitellatum	0.2	—	—	—	—
*Lepidium latifolium**	0.1	0.3	—	—	—

TABLE 2. CONTINUED

Name Total/mean transect length (m)	Cobble bars (n=15) 93.3/8.5	Vegetated streambed (n=17) 170.0/10.0	Riparian shrub (n=40) 371.2/9.3	Riparian forest (n=4) 208.5/52.1	Mixed pine forest (n=12) 84.4/10.6
Rumex triangulivalvis	0.3	0.3	—	—	—
*Plantago lanceolata**	0.1	0.2	—	—	—
Lupinus sp.	0.5	—	—	—	—
Equisetum arvense	0.7	5.3	5.3	0.3	—
Artemisia ludoviciana	0.3	0.1	0.5	1.2	—
Solidago canadensis	1.2	0.5	1.3	—	—
*Trifolium repens**	0.2	—	0.3	—	—
*Verbascum thapsus**	—	0.2	0.6	—	—
*Tragopogon dubius**	—	0.2	—	0.3	—
Arnica amplexicaulis	—	1.1	—	—	—
Smilicina stellata	—	1.4	—	—	—
Potentilla glandulosa	—	0.3	—	—	—
Galium triflorum	—	0.1	—	—	—
Equisetum fluviatile	—	0.1	0.6	—	0.4
Hypericum anagalloides	—	0.1	0.1	—	—
Cicuta douglasii	—	2.8	1.6	—	—
*Cirsium arvense**	—	1.9	0.2	2.3	—
*Conium maculatum**	—	1.7	3.7	8.5	0.7
Artemisia dracunculus	—	—	0.7	—	—
Fragaria virginiana	—	—	0.1	—	—
Phacelia heterophylla	—	—	0.1	—	—
Urtica dioica	—	—	0.3	4.5	—
Vicia americana	—	—	—	0.3	—
Heracleum lanatum	—	—	0.1	—	1.7
Wyethia mollis	—	—	—	—	0.2
Sidalcea glaucescens	—	—	—	—	0.3
Polygonum douglasii	—	—	—	—	0.1
Eriogonum umbellatum	—	—	—	—	0.1
Penstemon sp.	—	—	—	—	0.1
Layer Total	6.1	20.1	16.9	17.4	3.6
Ground Surface					
Litter	14.1	56.3	65.2	63.1	75.1
Boulders	15.6	3.9	4.7	5.6	1.5
Cobbles	49.5	19.7	1.3	1.2	—
Gravel	10.1	—	—	—	0.5
Sand	—	2.1	—	6.4	6.3
Silt/clay	3.6	—	0.2	—	—
Brush piles	—	1.0	7.8	3.7	—
Ground Surface Total	92.9	83.0	85.0	80.0	83.4

TABLE 3. PLANT SPECIES COMPOSITION AND ABUNDANCE IN RIPARIAN VEGETATION TYPES ALONG THE LOWER TRUCKEE RIVER, NEVADA. Abundance values are absolute percent canopy coverage. Introduced species are marked by an asterisk. Total and mean transect lengths, and ground surface characteristics for each type are also included.

Name	Cobble bars (n=20)	Vegetated steambed (n=25)	Riparian shrub (n=15)	Riparian forest (n=13)	Upland Shrub (n=17)
Total/mean transect length (m)	545.0/27.3	238.7/9.6	107.0/7.1	271.3/20.9	215.2/12.7
Trees					
Populus fremontii ssp. *fremontii*	—	—	—	70.1	—
Tall Riparian Shrubs					
Populus fremontii ssp. *fremontii*	—	—	0.9	7.8	—
Alnus incana ssp. *tenuifolia*	—	—	5.1	—	—
Eleagnus angustifolius	—	—	3.6	—	—
Layer Total	—	—	9.6	7.8	—
Medium Riparian Shrubs					
Populus fremontii ssp. *fremontii*	0.2	—	18.6	0.9	—
Salix exigua	—	—	4.8	—	—
Salix lutea	—	—	1.2	—	—
Salix lucida ssp. *lasiandra*	—	—	1.3	—	—
Alnus incana ssp. *tenuifolia*	—	—	1.0	—	—
Eleagnus angustifolia	—	—	0.9	—	—
Populus balsamifera ssp. *trichocarpa*	—	—	0.8	—	—
Layer Total	0.2	—	28.6	0.9	—
Low Riparian Shrubs					
Populus fremontii ssp. *fremontii*	0.1	0.3	19.5	—	—
Salix exigua	0.3	—	2.1	0.4	—
Salix lucida ssp. *lasiandra*	0.1	—	2.0	—	—
Alnus incana ssp. *tenuifolia*	—	—	0.5	—	—
Salix lutea	—	—	0.3	—	—
Layer Total	0.5	0.3	24.4	0.4	—
Upland Shrubs					
Artemisia tridentata ssp. *tridentata*	1.3	0.1	—	3.8	42.4
Chrysothamnus viscidiflorus	0.2	—	—	—	5.5
Sarcobatus vermiculatus	0.2	—	—	—	0.3
Prunus andersonii	0.1	—	—	—	0.1
Gutierrezia sarothrae	0.1	—	—	0.1	0.1
Chrysothamnus nauseosus	—	—	1.8	—	0.7
Shepherdia argentea	—	—	—	—	6.0
Layer Total	1.9	0.1	1.8	3.9	55.1

TABLE 3. CONTINUED

Name Total/mean transect length (m)	Cobble bars (n=20) 545.0/27.3	Vegetated steambed (n=25) 238.7/9.6	Riparian shrub (n=15) 107.0/7.1	Riparian forest (n=13) 271.3/20.9	Upland Shrub (n=17) 215.2/12.7
Grasses and Graminoids					
*Bromus tectorum**	0.3	1.1	0.7	—	1.9
Leymus cinereus	0.3	0.2	—	0.1	3.3
Carex lenticularis	0.1	—	—	—	—
Carex douglasii	0.1	0.2	—	—	—
Juncus balticus	0.4	0.5			
*Poa pratensis**	0.4	—	2.0	—	—
Eleocharis acicularis	—	29.4	1.0	—	—
Scirpus americanus	—	4.3	1.3	—	—
*Polypogon monspielensis**	—	2.7	2.4	—	—
Juncus effusus	—	0.9	0.8		
*Holcus lanatus**	—	0.9	2.0	—	—
Carex utriculata	—	—	1.1	—	—
*Phalaris arundinacea**	—	—	1.0	—	—
Carex athrostachya	—	—	0.4	—	—
*Hordeum brachyantherum**	—	—	0.1	—	—
Elymus trachycaulus	—	0.1	1.1	4.8	—
Distichlis spicata	—	—	—	0.1	0.3
Layer Total	1.6	40.3	13.9	5.0	5.5
Herbs					
*Lepidium latifolium**	4.4	29.8	21.8	6.8	1.0
*Melilotus alba**	0.4	5.3	9.1	—	—
Artemisia dracunculus	0.1	0.4	1.0	—	—
Epilobium ciliatum	0.1	1.6	0.6	—	—
*Trifolium repens**	0.3	0.8	1.3	—	—
*Salsola kali**	0.1	—	—	—	—
Artemisia ludoviciana	0.1	—	—	—	—
Xanthium strumarium	—	2.8	—	—	—
Mimulus guttatus	—	0.2	0.3	—	—
*Conringia orientalis**	—	—	3.1	—	—
Castilleja minor	—	—	0.2	—	—
*Plantago lanceolata**	—	—	0.1	—	—
Urtica dioica	—	—	0.2	—	—
Cicuta douglasii	—	—	0.1	—	—
Equisetum arvense	—	—	0.1	—	—
Layer Total	5.5	40.9	37.9	6.8	1.0

Table 3. Continued

Name	Cobble bars (n=20)	Vegetated steambed (n=25)	Riparian shrub (n=15)	Riparian forest (n=13)	Upland Shrub (n=17)
Total/mean transect length (m)	545.0/27.3	238.7/9.6	107.0/7.1	271.3/20.9	215.2/12.7
Ground Surface					
Litter	30.8	20.1	40.9	65.3	51.1
Boulders	0.9	—	—	—	—
Cobbles	28.4	4.0	13.8	1.0	2.3
Gravel	3.8	—	—	1.3	1.5
Sand	31.3	32.7	27.0	25.2	33.9
Silt/clay	1.6	30.2	—	—	—
Brush piles	0.3	—	3.0	1.2	0.3
Ground Surface Total	97.1	87.0	84.7	94.0	89.1

was substantially reduced from its typical abundance during wetter periods.

Discussion

The conversion of the riparian corridor of the Truckee River to urban, industrial, and agricultural uses, water resource development, and other human activities has led to a significant decline in the biological resources of the riparian corridor. Although some areas have recovered from earlier impacts, the type, degree, and extent of recovery from these actions varies among the study reaches. For example, the Lake Tahoe-Boca reach was intensively logged in the last half of the 19th century. Today, much of the riparian corridor in this area has natural vegetation with only 7% in either urban and industrial uses or otherwise disturbed.

In the downstream reaches between Boca (CA) and Vista (NV), human activities continue to directly impact between 25% and 29% of the riparian corridor. For the lowermost of these two reaches, which contains the city of Reno, this is a significant underestimate of the historic losses within the riparian corridor since the river in this area is contained between flood control levees.

The riparian corridor in the two reaches between Vista and Wadsworth is dominated by agricultural and industrial uses, or is otherwise disturbed. Only about 40% of the riparian corridor in these reaches remains in natural condition. Downstream of Wadsworth, the proportion of natural vegetation increases to between 55% and 70%.

Two aspects of the data are of particular interest in regard to ecological restoration within the riparian corridor. These are: 1) the relative impacts of introduced plant species; and, 2) the potential amount of habitat available for restoration. With respect to introduced plant species, the habitats vary when compared to each other as well as among reaches. Along the upper Truckee River, introduced plants include only grasses and herbs (Table 2). They are most abundant in the understory of the riparian forests where they comprise 47% of the total vegetative cover. Three species, *Poa pratensis, Hordeum brachyantherum,* and *Conium maculatum* account for most of this cover.

Along the lower Truckee River, the introduced shrub *Eleagnus angustifolius* is a minor component of the riparian shrub community, but here are numerous introduced grasses and herbs. Individual species of introduced grass comprise only a few percent of any community. The predominant introduced herb is *Lepidium latifolium,* which dominates the herbaceous layer of all natural vegetation but the upland shrub community. Overall, it accounts for 33% to 72% of the total understory cover, and is most abundant in the vegetated streambed and riparian shrub communities.

If one assumes that the total area currently occupied by agricultural and otherwise disturbed areas (including areas dominated solely by *Lepidium latifolium*) represents the maximum amount of area potentially available for habitat restoration, the three lower river reaches between Vista and Dead Ox Wash offer the most potential for restoration, with 280 ha, 238 ha, and 227 ha of these habitats, respectively. This is not, however, to say that potential restoration opportunities are not available, or should not be pursued, in other reaches. Opportunities are most limited in reaches where the floodplain is restricted to a relatively narrow canyon bottom. Examples include upstream of the town of Truckee where the already narrow floodplain is constrained by a highway and an increasing number of residences, and in the narrow gorge between Dead Ox Wash and Numana Dam. Urban and industrial areas in the vicinity of Reno also offer limited restoration opportunities.

The presence of suitable habitat is not the only factor constraining restoration opportunities. Aside from the obvious need for the cooperation of private landowner's, ecological processes must also be considered. As noted in the introduction, downstream of Numana Dam the river has incised deeply into floodplain terraces which formerly supported extensive stands of cottonwood forest. The scattered skeletons of dead trees and the few decadent living cottonwood trees which remain on these terraces suggest that groundwater levels in this area have dropped beyond that necessary to maintain trees.

Serious constraints on restoration potential also exist upstream of the area where significant channel incision has occurred. Flow regulation and water diversions have altered the magnitude, timing, frequency, and duration of flows in the river. These changes have had the greatest effect downstream of Derby Dam where the interbasin diversion of water to the Carson River drainage takes place. River terraces which currently support cottonwood forests are no longer flooded with the historic frequency, so conditions conducive to cottonwood (and willow) seed germination are less frequent. This partially accounts for the paucity of replacement cottonwoods in the shrub layers of the cottonwood forests, as well as the absence of any associated riparian shrubs. This absence, and the fact that *Artemisia tridentata* ssp. *tridentata* is the only shrub present in these forests, suggests that groundwater levels are below the effective rooting depth of riparian shrubs for an insufficient length of time to allow the establishment of any seedlings that might germinate during wet springs.

The existing riparian shrub communities along the lower river occur primarily on sandy deposits along the edge of the active channel. These communities, dominated by cottonwood saplings, were established after a period of high runoff in 1983 (Lisa Heki, personal communication, August 1998). In 1995, an estimated 50,000 new cottonwoods regenerated along the active channel in this area as a result of experimental flows patterned on a natural flow regime (Christensen 1996). Flow management in 1996 and 1997 resulted in additional channel reshaping and creation, and the establishment of an estimated 15 to 20 million cottonwood seedlings downstream of Wadsworth (L. Heki, personal communication, August 1998).

I had earlier expressed concerns that high flows might remove saplings already established in the active channel (U.S. Fish and Wildlife Service 1993). These concerns now appear unwarranted. Although the 1997 flood reached 23,000 cubic-feet-second, and removed some saplings that had established in 1983, many of these uprooted trees were deposited downstream where they resprouted after being buried in sediment. In addition, the flood rearranged channels and created side channels that provided additional habitat for cottonwood recruitment. This newly created habitat more than compensates for cottonwood regeneration lost to the flood flows (L. Heki, personal communication, August 1998).

Such remarkable short-term successes make the long-range prospects for the restoration and enhancement of the lower Truckee River appear highly favorable. With continued flow management directed toward maintenance of the regenerated cottonwoods in the active channel, riparian forests can be expected to develop and eventually provide suitable habitat for riparian forest associated plant and animal species. In addition, the erosive action of floods will be decreased by the network of roots associated with these forests and their aboveground vegetation (Gregory et al. 1991). Increased sediment deposition resulting from the enhanced retention of material in transport may lead to an increase in the general elevation of the streambed, thereby restoring the hydrological connection to the uppermost river terraces. In time, the river valley may once again resemble the one described over 120 years ago as consisting of "meadowlands . . . studded with fine large cottonwood trees . . . which were here and there grouped into delightful groves, sometimes unencumbered, but generally with a shrubby undergrowth, amongst which the "buffaloberry" (*Sheperdia argentea*) was conspicuous" (Ridgeway 1877).

Conclusion

This paper provides basic information on the species composition, structure, and areal extent of riparian vegetation along the Truckee River. These data, along with an understanding of hydrological processes such as flow magnitude, frequency, timing, and duration can guide land managers and biologists in their efforts to restore and enhance these habitats. Such actions will become increasingly important as the urban and rural populations of the west continue to grow.

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